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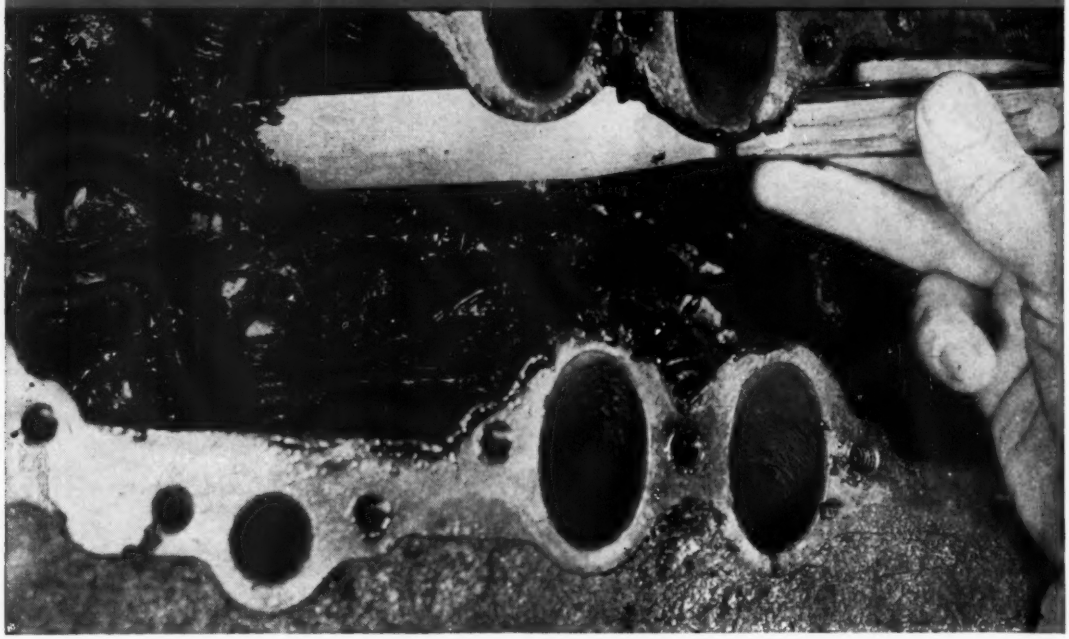
A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Low Temperature Sludge
in Automotive
Gasoline Engines

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

CONTROLLING
LOW TEMPERATURE SLUDGE



THIS photo shows the "gooey" mass that can form in automotive engines under low temperature driving conditions brought about by wartime restrictions. Low cooling system and crankcase oil temperatures resulting from short runs and slow speeds due to war-time gasoline restrictions, promote condensation of water, incomplete combustion and fuel dilution.

Care in the selection of the motor oil and in the operation and maintenance of the engine as recommended will do much to reduce sludge formation.

The lightest grade motor oil, consistent with the manufacturers' recommendations as set forth in the latest Texaco Automotive Lubrication Guides, and changed regularly, will help greatly to assure smooth operation and will reduce the danger of engine damage liable to be caused by sludge-clogged oil pump screens and oil lines.

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Low Temperature Sludge in Automotive Gasoline Engines

UNDER slow speed, or frequent start and stop or short trip operating conditions of passenger cars and in certain types of bus and truck service, a type of sludge is formed which has been appropriately referred to as *low temperature sludge or cold engine oil sludge.* Invariably this sludge formation is blamed on the engine lubricating oil. It is the purpose of this article to present information on low temperature sludge in gasoline engines, its manner of formation, its composition and the recommended practices to overcome it. A suggested method for cleaning sludged engines also is included.

NATURE AND METHOD OF FORMATION

Low temperature sludge may be described as a black, brown or grey colored deposit having a soft mayonnaise-like consistency. *It is formed in engines as a result of operation at low engine temperatures such as exist during starting, warm-up and also during intermittent start and stop and low speed driving.*

An engine is said to be operating at a low temperature or as a "cold" engine when cooling water temperatures and crankcase oil temperatures are below 140°F. Low operating temperatures also are considered to exist when crankcase oil temperatures are below 140°F. with cooling water temperatures above 140°F. This latter condition may occur during winter operation where cold air continually passes over the crankpan causing rapid heat dissipation while the cooling system thermostat maintains normal jacket temperatures.

Under these conditions of "cold" engine operation, moisture from the condensation of water vapor reaches the crankcase oil where it emulsifies with the other contaminants usually present in used engine oil such as fuel soot, lead salts, oil and fuel oxidation products, metal particles and dirt, to form a "gooey" pastey mass commonly termed low temperature sludge.

An increased rate of blow-by accompanies "cold" engine operation due to the greater piston and ring clearances that exist with the result that more contamination of the crankcase oil with fuel combustion products occurs. The source of the constituents of oil-free low temperature sludge are as follows:

Water

During the combustion of the air/fuel mixture in a gasoline engine, the oxygen in the air combines with the hydrogen in the hydrocarbon structure of the gasoline to form water (H_2O) which is present in the combustion chamber as a vapor.

Approximately one gallon of water is formed from each gallon of gasoline that is burned to completion. Under normal operating conditions, the major portion of this water vapor passes harmlessly out the exhaust. However, under conditions of "cold" engine operation, much of it condenses on the relatively cold cylinder walls; the water thus formed being scraped into the crankcase by the action of the piston rings.

Some of this water vapor also reaches the crankcase directly as a result of piston blow-by where it condenses on the relatively cold sides of the crank-

case and crankpan. In addition under certain conditions moisture in the air entering the crankcase through the breather may also condense on these relatively cold surfaces. One source of water which has nothing to do with "cold" engine operation but which occurs more often than is realized is cooling system leakage. With present-day gasket material, this possibility is decidedly prevalent.

Fuel Diluent

Over-choking and the incomplete combustion that results with cold running engines permits quantities of unburned and partially burned gasoline to dilute and contaminate the crankcase oil.

Fuel Soot

This material which is like lamp-black, is formed in the combustion chamber in rather large quantities under the rich mixture conditions which exist during starting and warm-up. It is also caused by incomplete combustion which accompanies "cold" engine operation. Fuel soot reaches the crankcase by mixing with the oil that is being returned by the piston rings. Some fuel soot also finds its way directly into the crankcase with the blow-by gases.

Lead Compounds

During the combustion of leaded gasoline, lead compounds are formed. These compounds are carried into the crankcase by mixing with the oil that returns from the pistons. They are also carried down by blow-by-gases. Aside from the fact that these compounds are present as a constituent of low temperature sludge, they are not harmful.

Oxidized Material

Due to the comparatively low oil temperatures which exist during "cold" engine operation, very little oil oxidation takes place. However, oxidized material is usually found in the analysis of low temperature sludge deposits. This material may be due to oil oxidation which occurred during the periods of normal or severe service preceding or following the sludge forming period. It might also result from slow oxidation of oil entrapped by the sludge.

Metals

Besides the presence of lead compounds resulting from leaded fuel combustion already discussed, iron is also found in varying amounts. Its origin is the normal wear of such engine parts as rings, pistons and cylinder walls. Under these low engine operating temperatures the amount of iron is increased by the accelerated wear of these parts caused by rusting due to condensed water vapor and by the corrosive action of certain acids formed when combustion gases combine with condensed water vapor.

Where aluminum pistons, copper-lead bearings, etc. are used, small amounts of these metals will also be found in the oil.

Dust and Dirt

Entry of these contaminants with the carburetor intake air or through the crankcase ventilating system constitutes the source of the silica usually found in this type of sludge.

In general, the sludge formed by the emulsification of the oil and water assisted by the other contaminants which act as emulsifying agents is not restricted to any one type of oil nor is it dependent on the quality of the oil. There has been some recent indication that heavy-duty detergent type oils are more effective in preventing the formation of this sludge than regular or ordinary types of motor oils. The field data still are rather confusing as the extent of testing has not been sufficient nor the results conclusive enough to warrant making any definite statement in this regard at the present time.

Sludge Composition

The results of analyses of several low temperature sludge deposits found in the crankcases of automotive engines operating under present-day conditions have been averaged and are as follows:

	As Received	*Oil-Free*
Oil, %	83.1	—
Water, %	6.2	36.7
Gasoline Diluent, %	4.7	27.8
Free Carbon (Fuel Soot), %	1.6	9.5
Oxidized Material, %	0.8	4.7
Free Mineral Matter, %	3.6	21.3
Chief Components	Lead, Iron	
Minor Components	Aluminum, Copper, Silica	

The source of the water and diluent has already been discussed. Free carbon found in this type of sludge is attributed almost entirely to fuel soot from the combustion chamber since negligible oil oxidation takes place to cause any carbon formation from that source. In addition to the source of the oxidized material already discussed, heavy ends of fuel may also constitute a portion of this material.

Free mineral matter is the insoluble material remaining after the oil, water, diluent, free carbon and oxidized material have been removed. It is composed of lead salts from leaded fuel combustion, metallic particles from engine parts and dust and dirt from external sources.

Effect of Wartime Gasolines

In order to increase the quantity and quality of gasoline being produced for military needs, both automotive and aviation, the Petroleum Administration for War has imposed certain limitations on the quantity, distribution and characteristics of gasoline produced for civilian use. There have been some recent indications that, under engine operat-

Figure 1—Low Temperature Sludge on Crankshaft Throws.

ing conditions promoting low temperature sludge, chiefly low cooling system temperatures and low crankcase oil temperatures, there is a tendency for certain wartime gasolines to be more prone to influence the formation of this sludge than pre-war gasolines. Brief but inconclusive investigations conducted so far tend to indicate that the chemical composition and volatility of these gasolines may be factors. Further studies in this connection are now in progress. These findings are important, however, since they show that it is more imperative than ever to maintain normal engine temperatures in accordance with accepted practices.

Effect of Low Temperature Sludge on Engine Performance

Besides giving an unsightly, dirty appearance to the engine interior, low temperature sludge can be decidedly harmful to engine performance. Clogging of oil pump intake screens and oil lines restricts the oil supply causing bearing failures and severe crankshaft scoring besides damaging other engine parts dependent on pressure feed for lubrication. Oil filters are quickly clogged rendering them inoperative for further sludge removal. Ring sticking and valve sticking also occur when this sludge is circulated with the oil. Oil ring clogging has also been experienced resulting in high oil consumption which, in turn, may also cause ring sticking and combustion chamber deposits. In the winter, freezing of the water in the sludge has been known to break oil pumps. In addition to the cost of parts replacement and overhaul time, the operator is also confronted with the difficulty of completely removing this sludge from the engine. Typical examples of low temperature sludge formation are shown in the accompanying figures.

Figure 2—Low Temperature Sludge on Sump Screen.

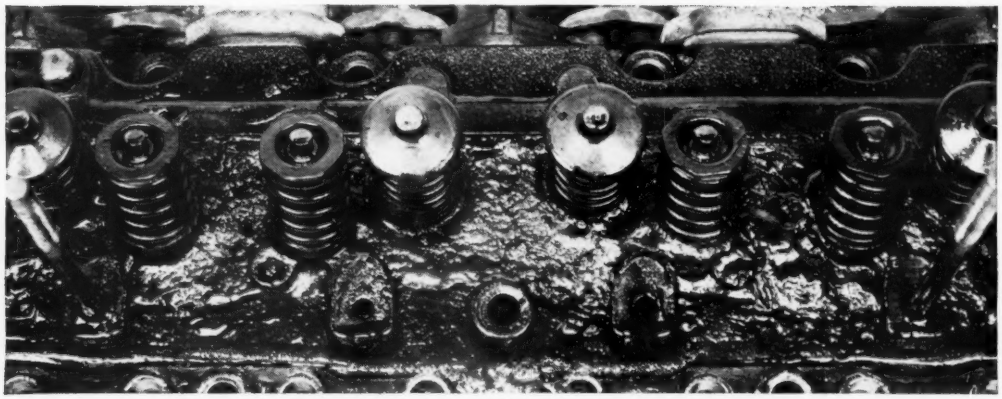

Figure 3—Low Temperature Sludge in Rocker Arm Chamber of Valve-In-Head Engine.

PASSENGER CAR ENGINES

Effect of Wartime Driving

Gasoline rationing and the limitation of maximum speed to 35 m.p.h. has brought about driving conditions which are conducive to the formation of low temperature sludge as previously described. Short runs with insufficient time for the engine to warm up, and intermittent start and stop and slow speed driving are conditions which promote the condensation of water vapor and unburned fuel vapors in the crankcase oil.

The absence of occasional high speed driving and long trips does not permit the crankcase oil to warm up sufficiently to evaporate these volatile contaminants as in prewar days.

Crankcase ventilation which aids in the removal of these volatile contaminants depends largely on the velocity of the air flowing past the ventilator outlet pipe and at the low road speeds existing today insufficient ventilation results.

Recommendations to Prevent Formation

Field experience has shown that adherence to the following recommendations will do much to prevent this type of sludge in passenger car engines during present-day wartime driving:

1. Change oil every 1000 miles or 60 days, whichever occurs first, in accordance with accepted oil change recommendations for wartime driving.
2. Drain crankcase immediately after road operation while oil is hot and before any settling occurs. Flushing the engine with a suitable flushing oil will assist in keeping it clean.
3. Use the lightest grade of high quality motor oil consistent with engine conditions and in accordance with engine manufacturer's recommendations.
4. Check cooling system thermostat for proper functioning and make sure it will provide rapid warm-up of the engine. If thermostat opens at too low a temperature, a higher temperature thermostat should be installed. Depending on the make of the engine, the type of thermostat, and also the nature of the antifreeze, the cooling system temperature should range somewhere between 160 and 180° F. — the higher the better.
5. Check crankcase breather to insure freedom from restrictions and clean and re-oil the breather cap air cleaner at recommended intervals. Adequate crankcase ventilation aids in preventing condensation of water and fuel vapors in the crankcase and valve chamber.
6. Clean and re-oil the carburetor intake air cleaner at recommended intervals. More frequent cleaning is required where much dust is encountered.
7. Replace oil filter at the mileage recommended by the manufacturer or more frequently if rapid clogging occurs.
8. Use a manually controlled choke sparingly during cold weather operation to prevent unnecessary crankcase oil contamination. Where an automatic choke is used, consult with car dealer to insure that choke is operating properly.
9. Cover radiator front to increase the rate of engine warm-up. In sub-zero temperatures, covers are absolutely necessary to get adequate warm-up. Care must be exercised to prevent overheating following the warm-up period.
10. Use proper heat range spark plugs and have them cleaned and adjusted at regular intervals.
11. Check ignition system regularly including timing and distributor points.

12. In extreme cases, installation of smaller sized jets in carburetor in accordance with manufacturer's recommendations may be necessary to correct poor combustion conditions due to rich mixtures.
13. Where loss in power is observed, check compression pressure and make necessary mechanical repairs including valve grinding and installation of new rings.

BUS AND TRUCK ENGINES

Types of Service and Operating Conditions

Usually bus and truck operation is of the heavy-duty type involving heavy loads with resultant high engine and oil temperatures. However, there are some types of service which tend to promote low temperature sludge in these engines. Door-to-door delivery and city bus services are examples of those in which this sludge can form quite easily, particularly during cold weather operation, unless proper precautions are taken.

Under these service conditions frequent stops and starts do not permit the engine and the oil to warm up sufficiently to prevent condensation of water vapor or to evaporate volatile contaminants in the oil. Crankcase ventilation which aids in the prevention and removal of these contaminants is, in some installations, dependent on vehicle speeds to a large degree and, therefore, is not too effective when comparatively low road speeds exist. In addition, considerable crankcase oil dilution results from extended idling during cold weather.

Operators of large fleets oftentimes have to store vehicles outdoors due to insufficient indoor storage facilities. During winter months, such outdoor storage invariably requires certain winterization practices to permit easy starting as well as to prevent freezing of the cooling system water since certain fleet operators in certain localities do not use anti-freeze. Some of these winterization practices call for idling of engines for short periods at scheduled intervals. Invariably, however, periods of extended idling inevitably develop and under these conditions, poor combustion at low engine temperatures coupled with insufficient crankcase ventilation causes low temperature sludge formations in crankcases and valve chambers.

Experience of Automotive Field

During a recent gathering of commercial fleet operators, and representatives of engine manufacturers, oil filter manufacturers and the oil industry to discuss the problem of low temperature sludge, the following observations were reported by *fleet operators* themselves:

1. Proper crankcase ventilation is very important.

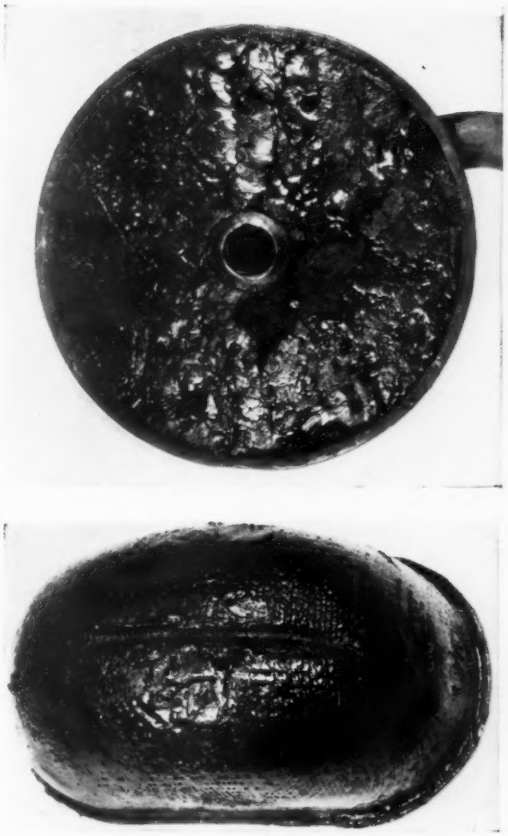

Figure 4—Low Temperature Sludge on Oil Pump Screens.

2. Oil filters aid slightly but should be used in conjunction with other factors.
3. Vehicles operating near bodies of water are more prone to form sludge than those operating away from water.
4. Mixing of different brands of oils may increase sludging tendency.
5. Radiator covers are effective for quick warm-up but cause overheating difficulties when wide atmospheric temperature changes occur.
6. Manually operated shutters are favored over automatic shutters by some operators but their use depends on the diligence of drivers.
7. High opening temperature thermostats are desirable.
8. Heavy-duty detergent type oils may tend to reduce sludge, but are not the whole answer and should be used in conjunction with other factors.
9. Changing pitch of fan blades, removing fans entirely and employment of heating coils around crankpan have been tried with varying degrees of success.

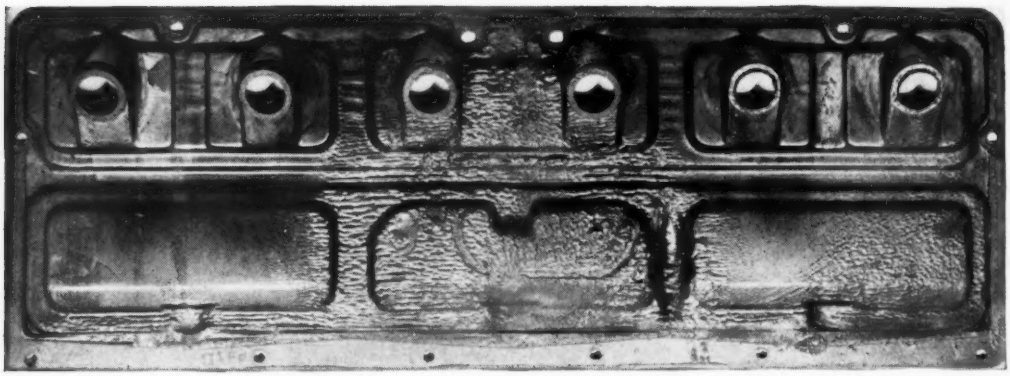

Figure 5—Low Temperature Sludge on Side Cover Plate.

10. One operator with 27,000 vehicles operating under various conditions experienced less than 0.1% engine failures per year from sludge troubles.
11. Engine design exclusive of crankcase ventilation is an important factor in the tendency to form sludge. Different designs operating side by side in Canada varied considerably in sludge forming tendency.
12. Present day oils and engines are less troublesome than those of several years ago.
13. Frequency of oil drains is also very important. More frequent changes should be made during cold weather.
14. Broken valve springs experienced with sludged engines are due to corrosion of metal by water in sludge.

Engine manufacturers pointed out that the best method to prevent low temperature sludge is by keeping engine temperatures up. In addition to the use of as high an opening temperature thermostat as possible, other methods to accomplish this as well as to prevent moisture condensation are as follows:

1. Installation of a pan beneath the engine to keep cold air away from the crankcase during road operation.
2. Use of a radiator cover consisting of a manually controlled curtain or an automatically controlled shutter.
3. Insulation of the crankpan with an insulating compound to prevent the rapid radiation of heat that occurs with a stamped steel pan.
4. Similar insulation of breather pipes and rocker arm cover to prevent condensation of water vapor.
5. Insulation of oil filter to prevent heat dissipation and where long oil lines are used they should also be insulated.

Effect of Heavy-Duty Detergent Type Oils

There has been considerable conjecture on the part played by heavy-duty detergent type engine oils in the prevention of low temperature sludge. However, as previously stated, the amount of information available still is insufficient to warrant making any definite statement in this regard at the present time.

In connection with oil ring plugging in gasoline engines which has been noted where low temperature sludge-forming conditions exist, laboratory tests under simulated low temperature operation in Chevrolet engines have shown that a heavy-duty

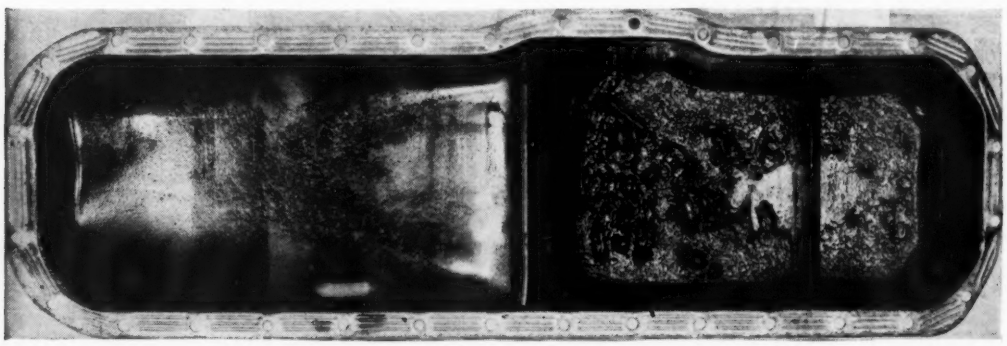

Figure 6—Low Temperature Sludge in Crankpan.

detergent type oil prevents oil ring plugging as compared to the clogged condition obtained with a regular straight mineral type motor oil. This comparison is shown in Figure 7.

In a recent SAE paper on "Cold Engine Sludge and Its Control" by B. E. Sibley,* the results of an extensive but impartial survey of the effect of heavy-duty detergent type oils on oil ring plugging in actual service are discussed. A total of 37 fleets involving some 37,000 vehicles contributed data. These fleets included public utility, municipal delivery, fuel and oil delivery, bus and taxi. This survey showed that under conditions of operation where there is a tendency for regular motor oil to cause oil ring plugging, the use of a heavy-duty oil nearly always either materially reduces or eliminates the trouble.

It is also interesting to note that the recent CRC Cold Engine Oil Sludge Group comprised of representatives of fleet operators, engine manufacturers, oil filter manufacturers and oil refiners issued the following statement with regard to low temperature sludge formation in Army vehicles: "It is the consensus of this committee that the type of oil being used by the Army is the best available at the present time for engine lubrication in Army Ground Force Vehicles. Any change in the type of oil used cannot be expected to improve cold engine sludging conditions." The oil used by the U. S. Army is of the heavy-duty detergent type meeting U. S. Army Specification 2-104 B. Further details on this type of oil may be found in *Lubrication* for November 1943 in the article on "Heavy-Duty Detergent Type-Engine Oils."

* Presented before the Society of Automotive Engineers, Philadelphia, Pa., June 28-29, 1944.

Recommendations

Combining the experience of fleet operators, engine manufacturers and lubricating oil manufacturers, the following recommendations are offered to prevent the formation of low temperature sludge in bus and truck engines:

1. Drain crankcase while oil is hot. Best time is immediately after engine is stopped following road operation. Draining of crankcase when engine and oil are cold is poor practice and leaves considerable quantities of used oil in the engine and sludge settlings in the crankpan.

2. Reduce time between oil drains if extended drain periods are being employed for one reason or another. Oil drains as frequent as 500 miles (or even less) may be necessary in some types of service and localities.

3. Check cooling system thermostat for complete closure when cold, and for proper operation when starting to open and when fully opened at manufacturer's specified temperatures. Use higher opening temperatur

Figure 7—Comparison of Ordinary Motor Oil and Heavy-Duty Detergent Type Oil with Respect to Oil Ring Plugging in Simulated Laboratory Low Temperature Tests. The Upper Illustration Shows Rings Operated on Ordinary Motor Oil. The Lower Illustration Shows Rings Operated on Heavy-Duty Detergent Type Oil.

thermostat where necessary to keep cooling system temperature at 160 to 180° F., depending on the type of anti-freeze used.

4. Cover radiator front to increase rate of warm-up. Also cover hood louvres completely during cold weather to increase underhood temperature.

5. Wherever practicable, enclose underpart of engine compartment completely to prevent cold air from striking crankpan.

6. Clean crankcase breather inlet and outlet at frequent periodic intervals. Clean and re-oil breather air cleaner at same time to prevent direct entry of dirt and dust into crankcase.

7. Clean and re-oil carburetor air cleaner at recommended intervals and more frequently if dusty operation is involved.

8. Use a good oil filter and replace cartridge at least at oil drains. Drain filter case periodically to remove water and clean case thoroughly at each cartridge replacement.

9. Refrain from idling engine to warm up in cold weather. Discontinue any winterization practices involving idling outdoors during cold weather.

10. Tighten cylinder head at periodic intervals to prevent cooling system liquid leakage into cylinders and check cylinder head gasket where persistent leakage occurs.

11. Adhere strictly to scheduled maintenance items involving checking of ignition system, carburetor, and compression pressures as well as other factors affecting proper engine performance.

Cleaning of Sludged Engines

The foregoing recommendations are intended primarily for the *prevention* of low temperature sludge formation in automotive gasoline engines. When sludged engines are encountered it might be advisable to clean them quite thoroughly before applying the foregoing recommendations. Complete disassembling for overhauling with its accompanying cleaning of engine parts is preferable. However, where overhauling is not fully justified the following procedure is suggested:

1. Drain crankcase immediately after road operation while oil is hot.

2. Drop crankpan and remove side cover plate and valve chamber cover. Remove as much sludge as possible from engine parts and interior by scraping and wiping.

3. Where spray equipment is available, spray valve chamber and engine interior with kerosine or suitable commercial solvent.

4. Remove oil pump intake screen and any removable oil lines and wash thoroughly in kerosine or suitable commercial solvent.

5. Remove oil filter cartridge and discard. Drain oil filter housing. Remove as much sludge as possible by wiping and scraping. Where oil strainers are used, wash elements thoroughly in kerosine or suitable commercial solvent. Pressure washing of these strainers is the best method to insure complete removal of any interior deposits.

6. Wash crankpan, valve cover, side cover plate and oil filter covers in kerosine or suitable commercial solvent before reinstalling.

7. Install new oil filter cartridge and/or clean strainer elements. Fill crankcase with a suitable engine flushing oil. Run engine as recommended by manufacturer of flushing oil. During running, watch oil pressure gauge closely and if pressure drops suddenly, stop engine immediately and check for clogged oil pump screen or other causes.

8. After flushing run is completed, drain crankcase and oil filter housings. Install new oil filter cartridge and/or clean oil strainer elements.

9. Fill crankcase with lubricating oil to be used. Check oil pressure before vehicle is placed in service.

10. Change oil after the first 500 miles or 30 days in passenger car service. In bus and truck service change oil after the first 500 miles and again after the next 1000 miles. This more frequent initial changing is for the removal of any further sludge deposits loosened by the lubricating oil.

CONCLUSION

The foregoing recommendations are believed to be those which the average operator should be able to place into effect without too much trouble. Employment of other practices discussed in this article should be at the discretion of the operator and after due consideration is given to the design of the equipment involved.

Although the information in this article applies primarily to automotive gasoline engine operation, it is also applicable for the most part to gasoline engines operating in all other types of service.

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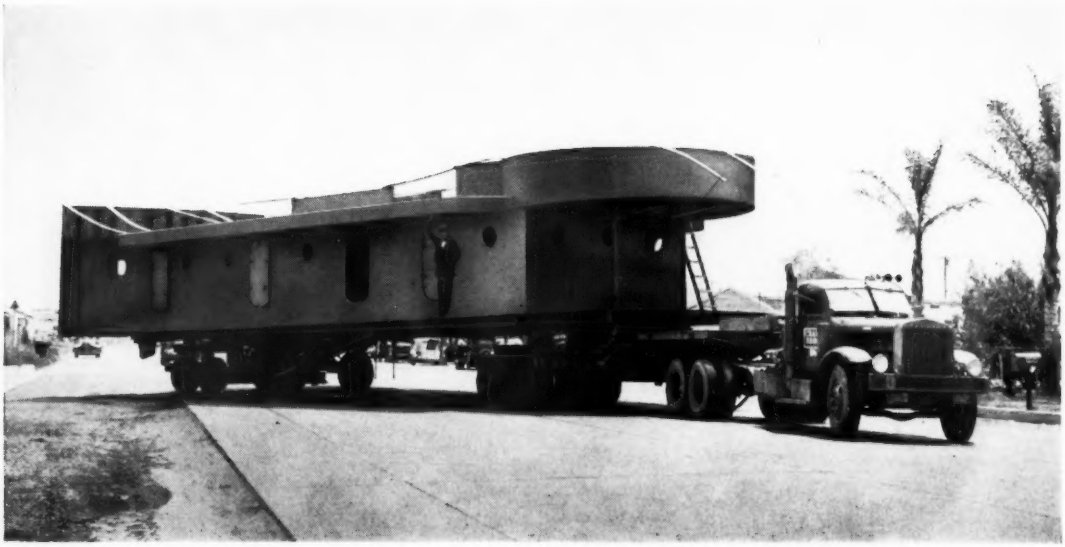

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